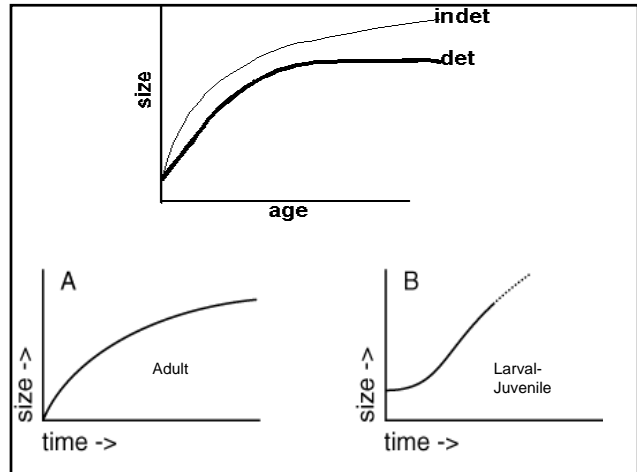


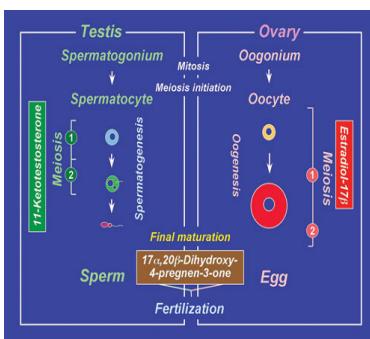
## Early Life History and Growth – Chapters 9 & 10

- 2 growth traits set fish apart from other vertebrates:
- Indeterminate Growth continual increase in length and volume
- Larval Stage – larval stage usually bears little resemblance to juvenile or adult



## Early Life History - Gametogenesis

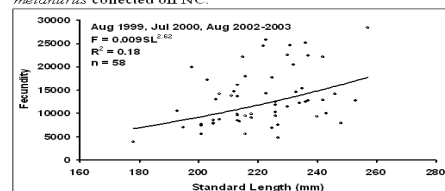
- 1) Gametogenesis
  - Spermatogenesis (sperm very variable)
  - Oogenesis (oocytes w/ yolk)
  - Vitellogenesis – yolk granules



## Early Life History - Fecundity

- 2) Fecundity = number of eggs released by a female
- – 1 or 2 up to millions; depends on life history v. Fertility (fish reabsorb unused eggs);

Figure 4. Relationship between fecundity and SL for ♀ *C. melanurus* collected off NC.



## Early Life History - Fecundity

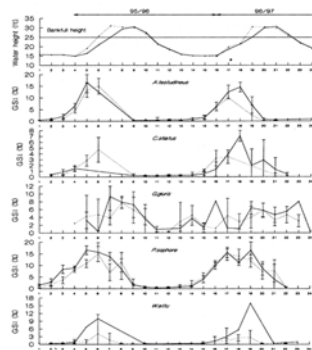
- 2) Fertility v. Fecundity (based on egg counts)
- Most marine fishes = pelagic and external fertilization;
- Most Freshwater = parental care/bottom or vegetation or nests. Demersal – laid on bottom

## Early Life History – Reproductive Effort

- 3) Reproductive Effort and Activity
  - Look at eggs – instantaneous versus cumulative measures
- Instantaneous vs. Cumulative
- Gonadosomatic index – GSI usually % weight – 5% (cichlids), salmonids (20%-30%) to 47% (eels) – males much lower

## Early Life History – Reproductive Effort

- 3) Gonadosomatic index
- Good for total spawners
- Underestimates – repeat, batch or serial spawners



## Early Life History - Fertilization

- 4) Fertilization – external in most; internal in all sharks and a few bony families;
- Some poeciliid live bearers = gynogenetic (use other males sperm to activate);
- Internal requires males have intromittent organ (claspers, gonopodium)



## Early Life History – Embryology

5) Embryology – after fertilization

Chorion hardens = water hardening



## Early Life History – Embryology

5) Embryology

- Oviparous – egg laying
- Viviparous – develop inside mother = live bearing – about half ( $\pm$  500) Chondrichthyes; 500 (2%) bony
- Ovoviviparity – inside mother but depend on yolk
- Development depends on temperature etc – causes meristic variation – usually colder means more scales, fin rays and vertebrae

## Early Life History – Embryology

5) Embryology

- Meristic Variation - Development depends on temperature etc – causes meristic variation
- Jordan's rule – latitude effects on meristic numbers - usually colder means more scales, fin rays and vertebrae – opposite guppies and plaice
- V relationship – fewer at intermediate

## Early Life History

6) Larvae

- Free embryo (free swimming young with yolk sac - alevin) to Fry (planktonic food)



## Early Life History

6) Larvae

- Direct v. indirect development – larval stage brief or non-definable (“miniature”) versus distinct metamorphosis

The diagram illustrates the developmental stages of a larva. It starts with 'Pelagic symmetric larvae' on the left, which are symmetrical and have eyes positioned dorsally. An arrow points to a middle stage where the eyes are beginning to migrate. A second arrow points to 'Benthic asymmetric adult' on the right, where the eyes have migrated to the ventral side, and the body is adapted for a benthic lifestyle. A curved arrow labeled 'Eye migration' connects the middle stage to the final adult stage.

## Early Life History

6) Larvae

- Larval Feeding and Survival
- Food very important right after yolk stage – important for population dynamics of commercial species – most larvae die in first week from starvation/predation
- Critical Period Hypothesis – Point of No Return

## Early Life History

6) Larvae

- Larval Feeding and Survival
- Match-Mismatch Hypothesis

The diagram illustrates the Match-Mismatch Hypothesis. It shows two scenarios: 'Match' and 'Mismatch'. In the 'Match' scenario, the 'Phytoplankton peak' (indicated by a downward arrow) and the 'Daphnid peak' (indicated by an upward arrow) occur at the same time. This is shown with a horizontal timeline where both peaks align. In the 'Mismatch' scenario, the 'Phytoplankton peak' occurs earlier than the 'Daphnid peak', indicated by a dashed vertical line between the two peaks. To the right of the diagrams are two vertical panels: the top one shows a microscopic view of phytoplankton, and the bottom one shows a microscopic view of a daphnid.

## Early Life History

6) Larvae

- Growth – More later under bioenergetics
- Gross Growth Efficiency - weight increase to weight food
- Assimilation Efficiency – food actually used

A microscopic image showing several larvae in a blue liquid medium. The larvae are translucent and have a distinct head and tail region. They appear to be in various stages of development or feeding.

## Early Life History

### 6) Larvae

Larvae usually not like adult – spines, large fins etc for anti-predator protection – as fish get older (larger) usually less risk of predation. Ecological, physiological and behavioral competence all improve.

Movement of larvae – interesting/debated – many marine fish spawn off shore. Larvae move inshore to weed beds/estuaries etc. – wind driven currents, tides etc.

## Individuals: Life Histories & Growth

- Chapter 10 – Juveniles to Adults - Growth
- 1) Juvenile when larval features lost vs. miniature adult
- Growth = metamorphosis
- Growth = change in size (body material)

## Life History Characters

- Age and size at maturation - Early v late = trade-off.
- More eggs older but may die first; younger fewer eggs and reduced growth and weaker state if they decide to reproduce.
- Fish under heavy predation reproduce sooner.

## Growth and Age

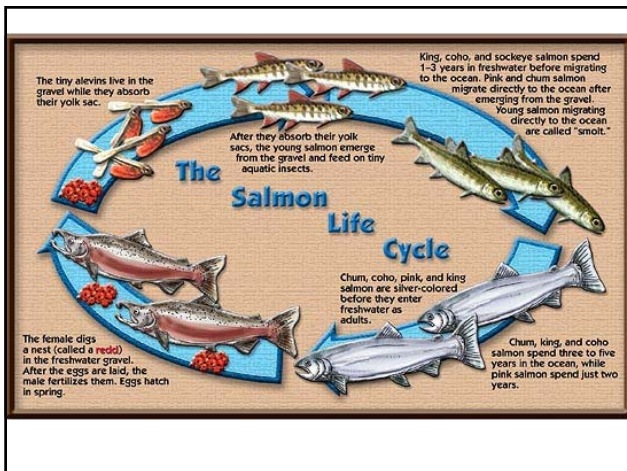
- Growth = any change in size or amount of body material, regardless of whether that change is positive or negative or temporary or long lasting
- Growth (energetically) = change in calories stored as somatic or gonad tissue (will discuss later)

## Metamorphosis

- Lampreys – ammocoetes to adult.
- Asymmetric flatfish.
  - I. Depression (dorsal ventral flat) v. Compression (lateral flat).
  - li. Incomplete ossification and rotation.
  - lii. Left eye flounders - sinistral.
  - Iv. Right eye flounders - dextral.

## Metamorphosis

- Smoltification – salmonids (fresh to saltwater).
  - Redds – eggs – alevins (egg sac) – fry – parr w/ parr marks – after months/years go downstream (smolts).
  - Countershade silvery; Streamline – loss lipids, more buoyant (inc gas volume) – hemoglobins change, gill structure (inc chloride cells) – reverse rheotaxis – imprint odor.
  - Hormonal control most changes; If don't get to sea they revert to parr and mature quickly (1 yr).



## Growth and Age - For Time T1 to T2 With Sizes Y1 and Y2

- 1) Absolute Growth =  $Y2 - Y1$
  - 2) Absolute Growth Rate =  $(Y2 - Y1) / (T2 - T1)$
  - 3) Relative Growth =  $(Y2 - Y1) / Y1$
  - 4) Relative Growth Rate =  $(Y2 - Y1) / [Y1 (T2 - T1)]$
  - Linear process but if exponential use instantaneous growth rates;
- $$G = (\log_e Y2 - \log_e Y1) / (T2 - T1)$$

## Length Versus Age = Growth Curves

- Fit model to curve – von Bertalanffy growth equation – Gompertz equation
- $L_t = L_{max} (1 - e^{-gt})$
- $T =$  time units ( $t_x - t_0$ ),  $L_t =$  length at time  $t$ ,  $L_{max} =$  maximum length,  $g =$  growth coefficient,  $e =$  base natural log

## Model Equations

**Linear model**

$$SL = m * \text{age} + b$$

**von Bertalanffy**

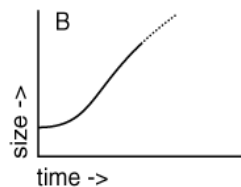
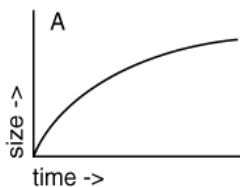
$$SL = L_{\infty} (1 - e^{-k(\text{age} - t_0)})$$

**Gompertz**

$$SL = L_{\infty} e^{-e^{-g(\text{age} - t_{min})}}$$

## Quantification of Size Changes (Growth)

- 1) Body length – standard length (SL), fork length (FL), total length (TL)

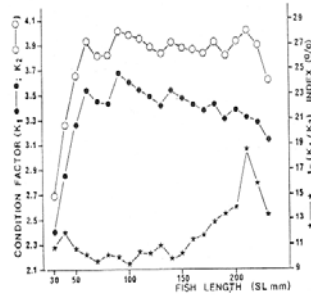


## Quantification of Size Changes (Growth)

- Weight – traditional measure growth & production
- Mass & Length – Easy to do
  - $W = aL^b$  where  $b$  usually 2.5 to 3.0
  - $W = \log a + b \log L$
- Good = more accurate as fish get larger;  $>$  or  $<$  3 means positive or negative allometric growth
- Bad = transient, water, lipids, gonads, stomach

## Other Quantification size changes

- K = condition factor for fish  
–  $K = W/L^3$
- Some use Wet v Dry weight v Ash Weight



## Other Quantification of size changes

- Proximate Analysis – categories of compounds in a mixture
- 1) Carbohydrates (low not typical)
- 2) Proteins w/ M.W. over 10,00
- 3) Lipids = good indicator

## Scale and Allometry

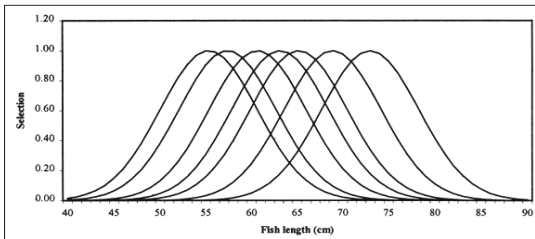
- Scale and Allometry – as fish grow dimensions of the body change – non-linear
- Types of Change:
- Dimension change (add mass length)
- Material change (cart to bone)
- Design change (anguilliform to carangiform swim)

## Estimations of Growth in Natural Populations

- Remember most techniques developed in temperate populations

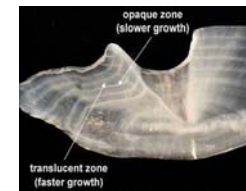
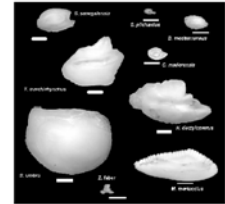
## Estimate Growth in Natural Populations

- Length Frequency Distribution in identifiable cohorts – Peterson Method. Assume cohorts cluster around mean
  - Advantages – easy to collect data; Low tech, anyone can do, need ruler or measuring board.
  - Disadvantage - Hard to analyze data, Bad in continuously breeding populations (tropics), better for young.



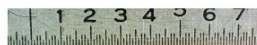
## Estimations Growth in Nat Populations

- Back calculation – Bony parts carry record of growth; otoliths, vertebrae, fin spines, scales, other hard body parts
- Advantages – Good data
- Disadvantages – expensive, time consuming, caution in ring interpretation, tropical no annual marks, need all size and age classes



## Estimate Growth in Natural Populations

- Mark Recapture – recovering marked fish of known age
- Tagging - clip fins, paint, tetracycline, pit tags, disks, flags, magnetic implants
- +++ Good data
- --- Expensive, time consuming – esp in large systems w/poor returns, tags influence, difficult recapture



## Estimate Growth in Natural Populations

- Raise in controlled environment
- Growth Rate =  $100 (\log_e W_f - \log_e W_i) / (t_f - t_i)$
- Good for aquaculture



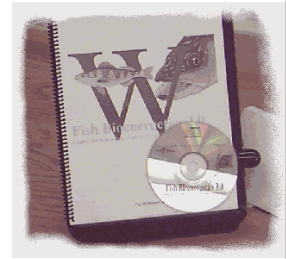
## Growth

- Usually annual – Daily in small fish
- a) Frasier-Lee  $L = a + bS$
- b) Regression
- c) Covariance
- d) Linear model approach

## Bioenergetics Model

Consumption =  
Metabolism  
(Respiration) + Wastes  
(Excreted) + Growth  
(Production);

$$C = M + E + G$$



## Bioenergetics Model

$$C = M + E + G$$

$C = (M = \text{respiration} + \text{active metabolism} + \text{SDA}$   
 $\text{specific dynamic action}) + (E = \text{egestion} +$   
 $\text{excretion}) + (G = \text{somatic growth} + \text{gonad}$   
 $\text{production})$   
 $= (R + A + S) + (F + U) + (B + G)$

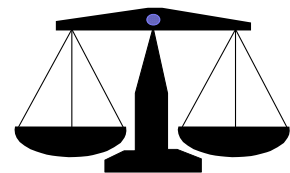
## Bioenergetics Model

$$C = M + E + G$$

Mass Balance  
Approach

Environmental  
Stress

Growth down if C  
decreases or M  
increases



### Bioenergetics Model

$$C = M + E + G$$

Consumption = proportion of maximum daily ration for fish at particular mass and temperature

= maximum rate = g of prey per g body mass per day

### Bioenergetics Model

$$C = M + E + G$$

Temperature dependence of consumption

Different functions

### Bioenergetics Model

$$C = M + E + G$$

Respiration is also dependent upon fish size, temperature and activity

Different functions

### Bioenergetics Model

$$C = M + E + G$$

Egestion and Excretion is constant proportion of consumption or as function of temperature and consumption

Different functions

## Bioenergetics Model

Scaling Individuals to Populations

Cohort = group of similar sized (aged) fish of the same species experiencing the same environmental conditions (temperature, diet, growth and reproductive losses)

Combine cohorts for population

## Bioenergetics Model

Population Mortality

Mortality = important population process

Natural and fishing